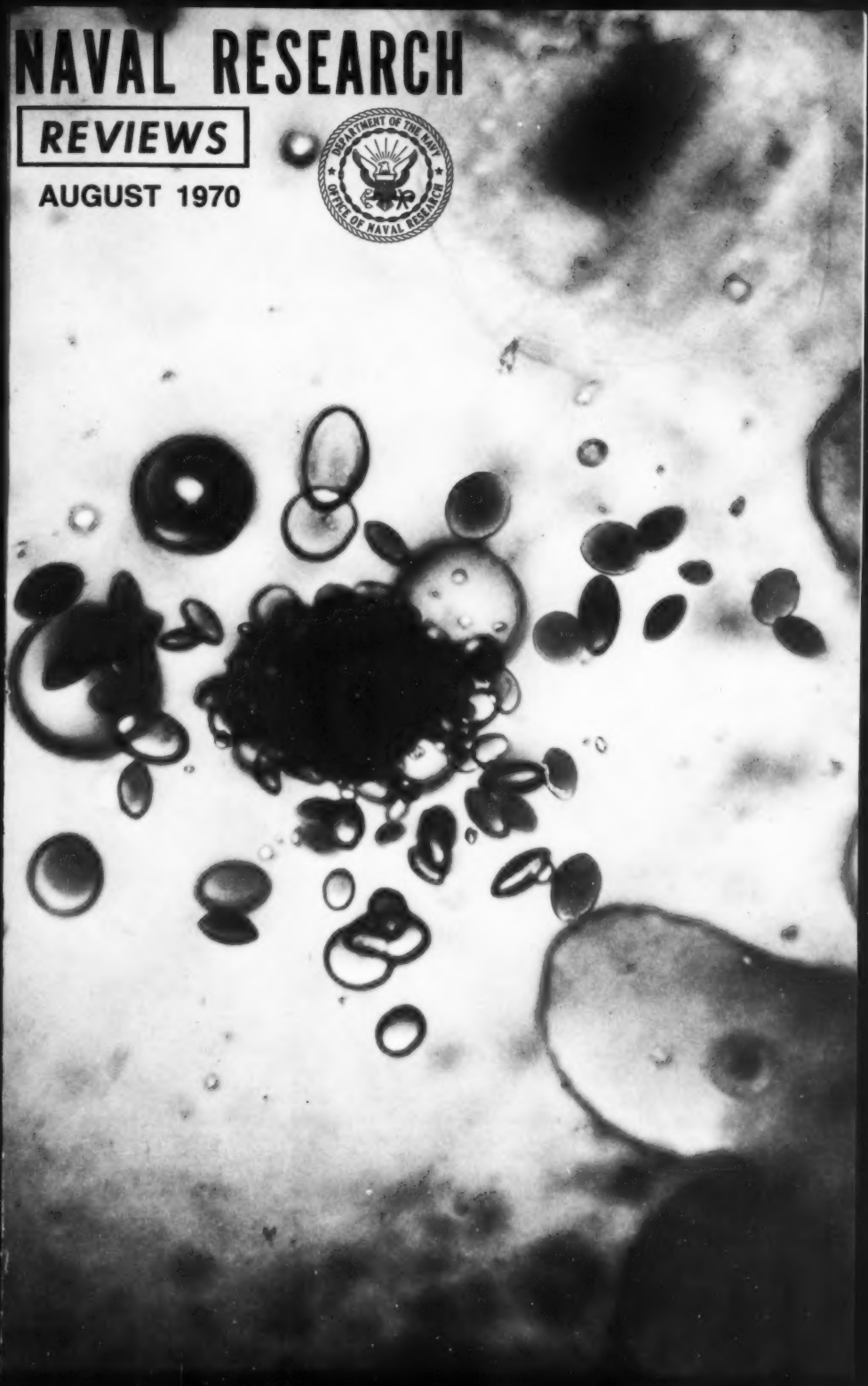
NAVAL RESEARCH

REVIEWS

AUGUST 1970



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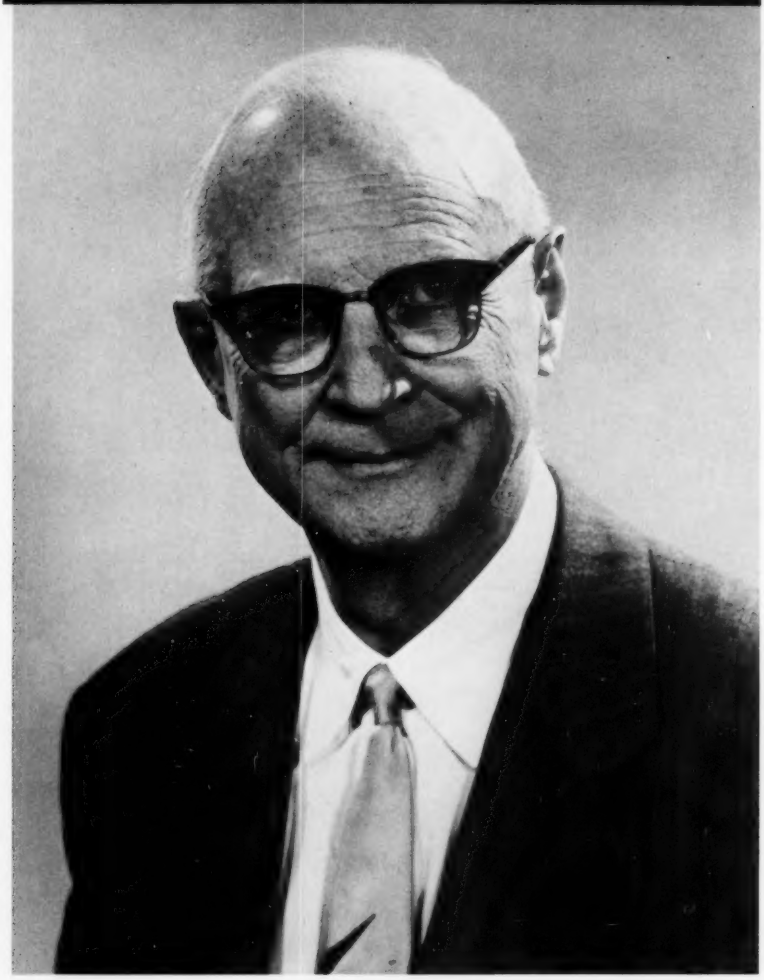
Portraits in Science



Among Dr. Guilford's many contributions to science, his work in psychometrics, which pioneered the joining of quantitative and experimental psychology, is most renown. Dr. Guilford developed a comprehensive and systematic theory of the intellectual abilities known as the structure of intellect which is now an established and widely used system. Since 1949 to the present the Psychological Sciences Division of the Office of Naval Research has provided Dr. Guilford yearly research contracts. Dr. Guilford is Professor Emeritus of Psychology at the University of Southern California. Dr. Guilford is a member of the National Academy of Science and a past President of the American Psychological Association which gave him the Distinguished Scientist Award in 1964.

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Human Memory as a Data Source

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An investigation into the validity of human judgment of task duration and the variables affecting that judgment is being made at the University of California at Los Angeles under the sponsorship of the Office of Naval Research. This study is part of the continuing UCLA research into advanced analytical methods to assist management decision-making.

Computerized analytical methods such as systems analysis, operations analysis, simulation, CPM/PERT and Work Study have substantially augmented requirements for accurate task time data. Because of the relatively high cost of obtaining this time data from empirical sources, the UCLA research team has been investigating the use of human data sources. If human judgment of task time is to become a primary data source, then a precise methodology must be developed which covers all aspects of data procurement. This is the purpose of the UCLA project.

The development of advanced Naval logistics systems require improvements in methods for making optimum use of limited resources. This task is concerned with the development of computer simulation techniques for evaluating and improving planning and logistics support procedures. In particular, the research will concentrate on simulation techniques related to work load planning and scheduling and material movement models. By using the concepts of general purpose simulation methods, new techniques will be developed to extend the general capability. Such extensions will include procedures for using nomographs and human memory recall for estimating input variables and the use of statistical methods for evaluating the output of the simulation.

During the past year research concentrated on the system analysis of an ocean terminal, utilizing a recently developed general-purpose transportation and physical distribution system simulator. Results of the simulator indicated that certain piers and equipment as well as system operating rules were causing congestions, delays and incurring high costs. Through simulated increases to personnel and equipment, system imbalances were corrected, through-put increased while direct operating costs per ton of cargo outloaded was reduced.

The Methodology

A method for obtaining task times from experienced workers has been developed and successfully demonstrated in several pilot studies.

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Time information is obtained from production workers who actually perform the task on the line item level. They are interviewed individually and asked to estimate task time and the probability that a given time will occur. These estimated times are based on their total past experience with a task, in many instances covering large numbers of occurrences. The end product of the interview is a histogram based on the estimated times and the probability of their occurrence (Figure 1).

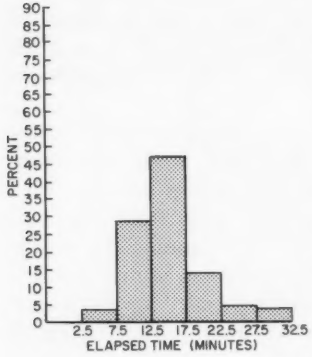

Figure 1 — Estimated times for silver braising four-inch copper-nickel pipe, subject No. 16 Long Beach Naval Shipyard

For example, according to subject 16, the task described in Figure 1 would be completed in approximately 5 to 25 minutes. Most frequently, or 46.3 percent of the time, it would be completed in about 15 minutes. An additional 4 percent would be completed in about 5 minutes, and another 4 percent in about 25 minutes. These variations in expected times for a single worker reflect changing human, environmental and task conditions. Changes due to human factors are changes in the mental and physical state of the worker. Environmental changes occur in weather, noise level, air pollution, space, and the like. These kinds of changes apply generally to all tasks in some degree. Task variation however, is specific and depends on the nature of the task. Time estimates in Figure 1, silver braising 4-inch copper-nickel pipe, may vary because:

- first joints require more torch time than subsequent joints,
- wait time while the torch heats is determined by the size of the braising tip,
- access to the pipe varies considerably when the work is to be performed on the ship.

Much of the field work for this project was carried out at the Long Beach Naval Shipyard (LBNSY) where individual shipyard workers were interviewed regarding the performance of their tasks. An example of an early test of the methodology is shown in Figure 2. Estimated times for experienced workers are compared with observed times

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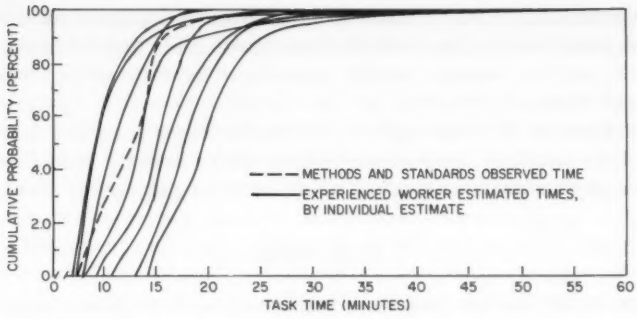

Figure 2 — Observed and estimated times for silver braising four-inch copper-nickel pipe, experienced workers Long Beach Naval Shipyard

obtained by Methods and Standards at the LBNSY. The task covered is silver-braising 4-inch copper-nickel pipe on board ship.

The methodology is dependent upon subjective judgment, a data source particularly vulnerable to bias. The interview method therefore provides for cross checking and other techniques designed to identify and minimize bias. The use of subjective methods is justified if the validity of those methods can be demonstrated. The test of validity pictured in Figure 2 was one of a number conducted for this purpose.

Project TRANSIM (Transportation Simulator) at UCLA, has successfully used its simulator, TRANSIM, to demonstrate the feasibility of utilizing such histograms as direct input in its extensive computer simulation of complex, real-world system problems. Simulations based solely on time estimates of "experts" have provided output which compared favorably with real system operating records. For example, recent computer simulations of railroads, marine ports, motor carriers, industrial processes, hospitals, ship fleets and physical distributions, all have been based on the human data source and have produced valid results.

The methodology has three distinct advantages. (1) It is simple. An interviewer with experience in Industrial Engineering or Industrial Psychology can be trained to use the methodology in less than a week. Relatively inexperienced staff at the Long Beach Naval Shipyard were able to properly conduct data collection interviews for a complex network analysis of a ship conversion project. A Preliminary User's Manual is being prepared, which should eliminate the special training requirement. (2) It has a wide application. The methodology is applicable wherever a man's experience with a given task qualifies him as an "expert" to describe the variations in elapsed times required to perform that task, and the probabilities of occurrence of different cycle times. (3) Time data can be obtained quickly and easily. Major savings in time

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and expense are realized because large quantities of data may be obtained at a minimum cost in time and staff personnel. Each task being analyzed requires, on the average, twenty minutes of interviewer and "expert" estimator time.

As a basis for decision-making, the methodology compares favorably with other methods for estimating task costs in time and resources, and it is applicable in many areas where no other data source is available.

Field Studies

Early in the UCLA project, a preliminary questionnaire format was devised and tested in a series of interviews with "experts" including UCLA faculty members and graduate students, and butchers in a custom meat market. The subjects were asked to estimate durations of specific tasks which they had performed repeatedly in the past.

A brief study was also made in the repair facility which services University of California motor pool cars on the Los Angeles campus. Time estimates for engine and brake overhaul jobs were obtained from highly experienced shops mechanics. Cross validation of estimates was made by comparing histograms obtained from mechanics with those obtained from the shop foreman. The results indicated highly satisfactory correlations between estimates from the two sources.

A pilot study was then conducted at LBNSY with one of the objectives being the identification of variables affecting human storage and retrieval of time data. The specific work task selected was the silver braising of 4-inch copper-nickel pipe; fifteen machine shop journeymen and apprentices were interviewed. Time studies originally used for developing engineering performance standards were available to provide a suitable standard against which to measure the validity of the time estimates obtained from the shop personnel. Satisfactory correlations were obtained with estimates from experienced men; experience and recency and continuity of experience appeared to be important factors.

The procedure and questionnaire format were modified as a result of the pilot study and plans were made for a more rigorous test of the methodology. The task selected for the test was to replace and secure manhole covers, an operation frequently performed on ships under repair in the LBNSY. The shipyard staff cooperated by providing 52 time samples and preparing the data for the comparative analysis. Subjects were 20 shipyard workers; fifteen of them were experienced and five were inexperienced. The investigator interviewed each subject for approximately 20 minutes in locations as close as practicable to the actual work site but free of disruptive factors such as the presence of supervisory personnel, noise, or interruptions. Subjects were required to make direct verbal estimates but were allowed to use point or interval values or both. Personal data was obtained following the time estimates

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in order to avoid prejudicing estimated times. At a separate time and place, supervisors were asked to evaluate the subject's speed, quality of performance and reliability.

Cumulative frequency distributions for shipyard observed times and for the estimates obtained from the 20 subjects are compared in Figure 3. As shown, subjective estimates of task-time were slightly longer than the observed data. Several factors may account for the difference. First, the workers are usually aware that they are being observed; hence, the observed sample might not be representative of the population due to social pressure, competitive spirit and job security. Second, when experienced and inexperienced workers' estimates were analysed separately, it became apparent that the differences between observed and estimated times reflected the differences in worker's experience. The variability was significantly reduced when estimated time values were adjusted for the differences in worker experience by applying a learning curve correction (Figure 4).

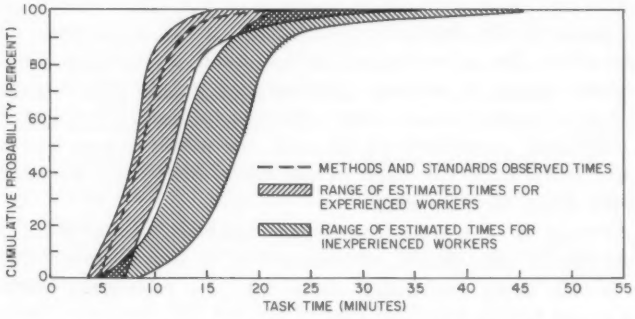

Figure 3 – Observed and estimated times for replacing and securing manhole covers, Long Beach Naval Shipyard

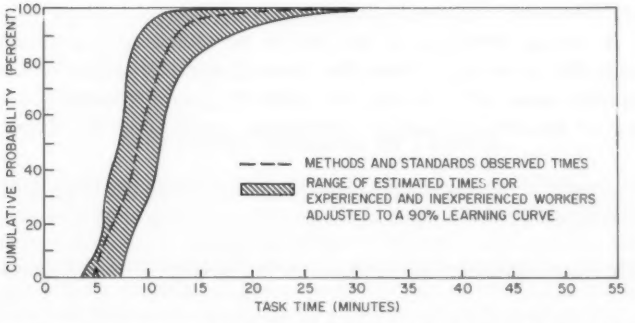

Figure 4 – Observed and adjusted estimated times for replacing and securing manhole covers, Long Beach Naval Shipyard

The influences of education, age, personality, speed and quality of performance will be studies in subsequent phases of this investigation. In addition, plans for the continuing development of the methodology include an investigation of:

- task variables such as complexity and duration,
- reliability of point versus interval estimates,
- effects of preliminary instructions, and
- effects of environmental conditions such as noise level, work space, and temperature.

Evaluation and Application

The empirical data and the results of our investigation have led to several general conclusions concerning human storage of time data and the most effective means of retrieving that data from human store:

(1) Humans store time data in natural units which are bounded by some change in the event. These changes, which are bounds of a unit of time, affect the subject's judgment of event duration. A long bound or a bound strong in intensity increases the judged length of the unit. So that, if a worker travels some distance to a work site and then returns following completion of the task, we would expect him to have included in his estimate some of the travel time even though he was asked for actual working time.

(2) Bounds of time units function as "anchors"; when these anchors are not clearly established, estimates tend to move toward the mean. Thus, a man being questioned about his time experience with a task is best asked for the extremes first.

(3) Past experience with subjects indicates that samples of task time which are unusual or atypical are recalled best. There is, therefore, added reason to believe that more reliable information is obtained when the extreme times are established first.

(4) A precise definition of the task to be estimated is prerequisite to a successful interview. When the investigator had difficulty obtaining a plausible range of estimates, the difficulty could frequently be traced to lack of investigator-worker agreement concerning the scope of the task.

(5) Carefully prepared preliminary instructions were important to the success of the interview.

Valid time estimates depended on the subject's comprehension of:

(a) the purpose of the interview
(b) the significance of the data and the role it was to play

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(c) examples of previous application of the methodology
(d) the scope of the task and its precise definition
(e) the information required

In addition, the following tentative hypotheses were suggested by the investigation:

(a) human ability to store time data is often underestimated
(b) inefficient retrieval of time information from human store is frequently due to inadequate methodology
(c) "experts" who have never consciously considered the time factor in an event are capable of accurately estimating its duration.

The methodology has been used to extract and organize information in several widely different problem areas. A simulation analysis of convalescent centers in Pasadena, California, and Honolulu, Hawaii, employing such data, led to suggestions for changes which, if adopted, should improve patient care, streamline hospital routines, simplify and expedite office procedures, and reduce hospital operating expenses.

At the LBNSY the human data source has been used to generate input data for a computer simulation of 270 individual work tasks which constitute a ship weapon system conversion. Estimates of resource requirements were also obtained from the human source. Utilizing such data, simulation runs on a critical path network model showed

- the probability that any line item would be on a critical path,
- the probabilistic utilization levels of each resource at any time during the conversion,
- a range of expected completion times and the probability of their occurrence, and
- probabilistic start and finish times for each line item.

The feasibility of the technical approach was successfully demonstrated in this phase of the investigation. Amplification and refinement of the technique and larger scale demonstration of the generality of its application are the present aims of the project team.

Thermionic Emission in Liquids

Dr. Paul Delahay recently reported the first description anywhere of thermionic emission by solvated electron solutions and by liquid systems at room temperature. The solution observed was sodium in hexamethyl phosphoric triamide. The thermionic emission was established by (a) near perfect rectification at the solution gas interface; (b) measurement of drift velocity of charge carriers in the gas between the solutions and collector; (c) analysis of electrical conduction in the gas phase. Measured currents were corrected for back scattering of electrons in the gas phase. The apparent work function is near 1.0 electron volts.

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Optimum Altitudes for Passive Ranging Satellite Navigation Systems

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Applications Research Division
Naval Research Laboratory

Navigation is an old art, one of the oldest known to man. The word itself is derived from the Latin *navigatvs*, a combination of the words for ship *(navis)* and to direct *(agere)*. Early navigation consisted of measuring the altitude of known stars to obtain latitudes. One sailed to the desired latitude and then east or west to the proper longitude. To determine longitude, a timepiece was required. The earliest timepieces used for this purpose were the moon and, for greater accuracy, the moons of Jupiter. In due course, the chronometer came into general use, and so matters remained until the invention of radio. Various radio systems were designed which improved the availability of fixes, but in most cases not their accuracy. It took the advent of the near earth satellite to bring a significant worldwide improvement in fix accuracy. The first satellites used for this purpose were low altitude (600 miles) polar objects that transmitted continuous frequency (CW) response.

This paper discusses a method for determining optimum altitudes for navigation satellites having different types of transmission than the present units.

A navigator can find the position (or a component of position) of a satellite by measuring the range to the satellite, by measuring a derivative of position, or by an angle measurement. A direct measure of range has the advantage of providing great accuracy, relatively simple calculations to find a line of position, and relative immunity to problems due to unknown navigator velocity.

Ranging can be accomplished by an active method in which the satellite is interrogated. The difficulty with active ranging methods is that the navigator must transmit and possibly give away his position. A second difficulty is that the technique has a saturation level.

In order to circumvent these difficulties, a passive ranging technique was conceived at ONR in 1964. Since that time it has inspired other navigation proposals and has become a prime candidate for a Defense Navigation Satellite System. Work has been done on this project both at NRL and, under ONR contract, at the Astro Electronics Division of the Radio Corporation of America. Funding is and has been provided by the Naval Air Systems Command.

Passive ranging is accomplished by having electronic clocks located both in the satellite and in the navigator's receiver. These clocks are

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composed of stable oscillators and counting circuits. If the counting circuits are originally synchronized, the signal received will be out of phase with the locally generated signal and, by measuring this phase difference, the distance between satellite and navigator can be inferred. On the other hand, if the clock circuits are not synchronized, they can be synchronized by using more data than is required for the fix. This overdetermined fix can also be used as a time transfer device to synchronize clocks wherever desired.

The attractiveness of a range measurement, besides its inherent accuracy, is the ease with which such a measurement can be converted to a line of position. Figure 1 shows why this is so. In this figure it is seen that the measurement of range to the satellite is analogous to the measurement of a zenith angle to a star having the same geographical position as the satellite. It is using a measurement of distance to measure an angle.

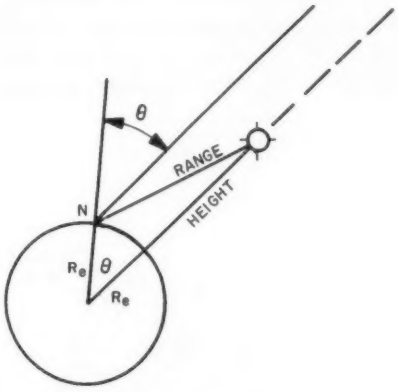

Figure 1 — Transform to celestial navigation

Since this measurement is analogous to a sighting of a sextant, all of the old techniques developed by celestial navigators over the past centuries can be used with this new one. Especially suited for this purpose is the intercept method due to the nineteenth century French navigator Marcq St.-Hilaire. His method involves making calculations with respect to an assumed position near the observer (rather than the geographical position of the star). An observation is then made and checked against the value calculated. The difference (or intercept) is then found. Using a suitable scale, the line of position (LOP) is plotted at right angles to the proper azimuth line at the intercept point. Two sightings provide two lines of position and their crossing point is a fix. Figure 2 illustrates such an intercept chart for a satellite operating in the time domain.

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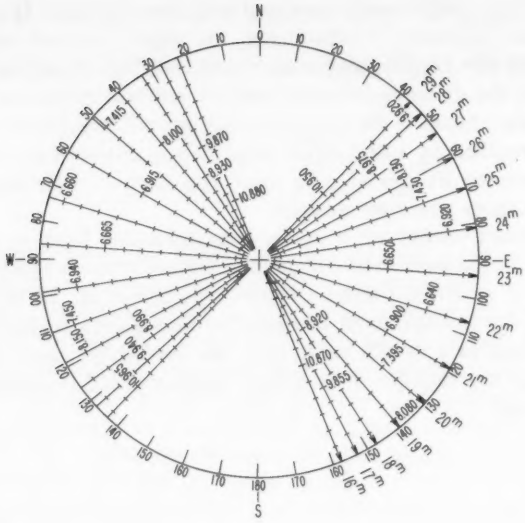

Figure 2 — Precomputed intercept chart

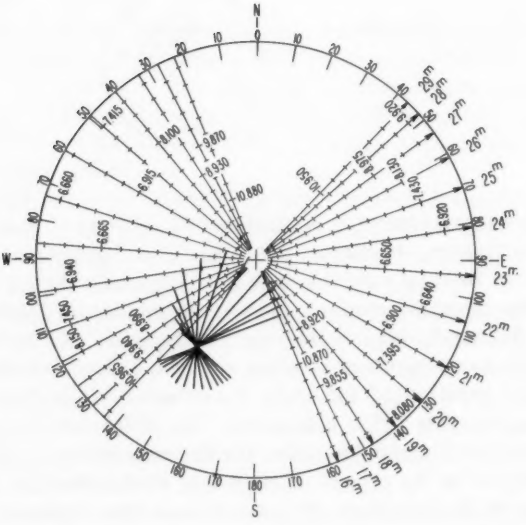

Figure 3 — Fix determined on intercept chart

Figure 3 shows the result one would obtain if the measurements were perfectly made. All of the LOPs intersect at the same point, and this point gives the fix. Figure 4 shows an intercept chart in which the navigator's and satellite clocks are not synchronized. Under these conditions, the LOPs describe chords of a circle whose center is the observer's position and whose radius is the error in clock synchronization. With such a chart one can estimate the correction needed, apply it to the measured values, and replot the fix.

A similar type of intercept chart can be made for doppler satellites. With these, the azimuth lines do not point to the geographical position but rather point in a direction nearly at right angles to it. The process of finding LOPs is similar if one now substitutes frequency for time delay (or distance) in the previous case.

Passive ranging satellites can accommodate a number of different types of users as, for example: range, range difference, absolute doppler, relative doppler, and a combined range plus doppler user. The range difference method requires the presence of more than one satellite, and absolute doppler, knowledge of satellite and user frequencies. For low altitude satellites, the combined range and doppler satellite is especially attractive as it allows a user to obtain a nearly instantaneous fix from a single satellite.

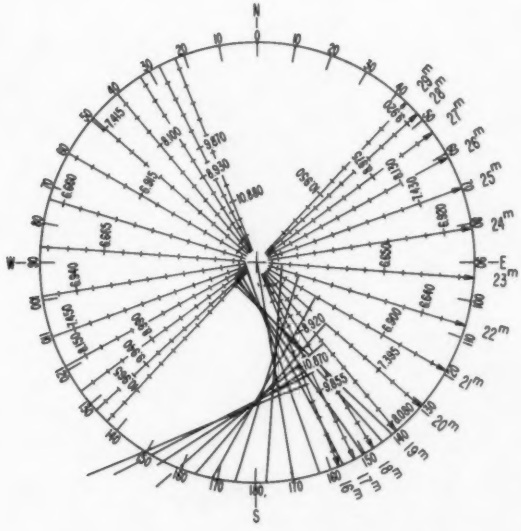

Figure 4 – Intercept chart showing effect of synchronization error on plot

Relative doppler has been demonstrated by the TRANSIT project, an outgrowth of an idea conceived at the Applied Physics Laboratory of Johns Hopkins University. The passive ranging and absolute doppler technique have been demonstrated by the satellites shown in Figures 5 and 6. These satellites have also been used to transfer time between distance points, and the second satellite is presently being used for geodetic purposes.

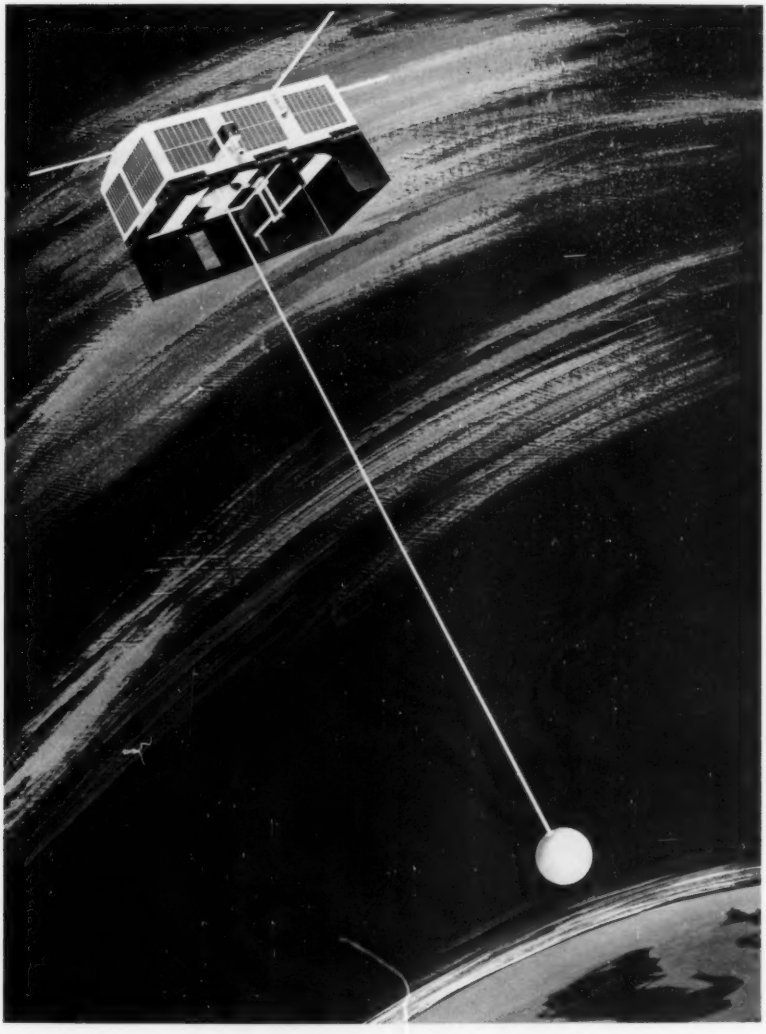

Figure 5 — First experimental satellite

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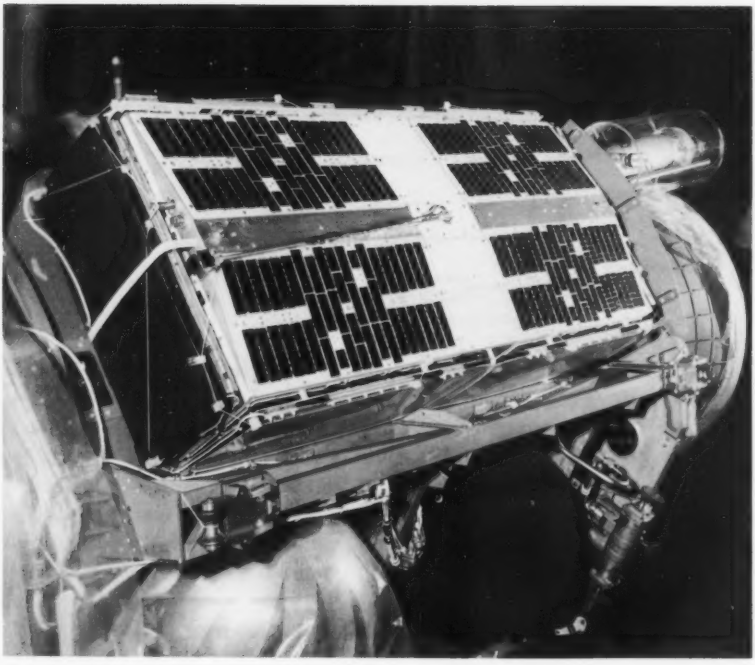

Figure 6 — Second experimental satellite

Both of these satellites orbit at low altitudes, approximately 600 miles in the same altitude range as is used by the craft of Navy Navigation Satellite System (TRANSIT).

While the low altitude satellite has provided a great improvement in accuracy over other methods, it does have a number of limitations in coverage and accuracy. Among these are the following:

- It provides but intermittent fixes for users. A large number of satellites is needed for continuous coverage.
- The accuracy obtainable for satellites in the 600 mile range is limited by the unknown drag component in the predicted satellite position.
- The accuracy is also limited by insufficient knowledge of gravitational anomalies. (These anomalies are larger at low altitudes.)

Figure 7 illustrates the first point. The radius of coverage at low altitudes is seen to be less than 1/3 what it is at high. Only relatively slow improvement occurs above an altitude of 6000 miles.

Figure 8 illustrates the change of drag with altitude. It is seen to decrease very rapidly.

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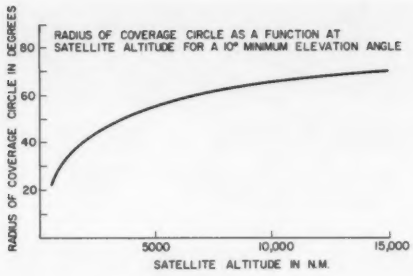

Figure 7

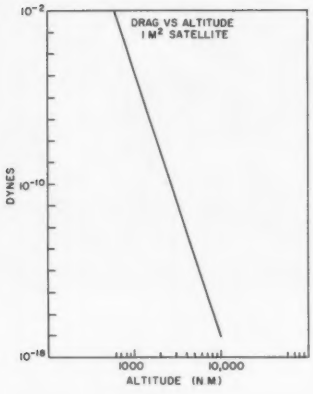

Figure 8

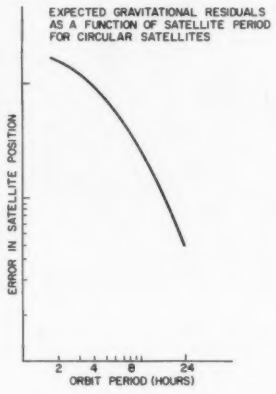

Figure 9

Figure 9 shows the calculated decrease in expected error for gravitational anomalies (as determined by the Naval Weapons Laboratory).

The difficulties posed by these problem areas decrease rapidly with altitude. When a requirement for a system having even greater accuracy and continuous three-dimension navigation appeared, it was natural to look at the higher satellite constellations and the required ground station.

While satellites form dynamic constellations, the layout of ground stations can be described as a static constellation. What is said about one applies somewhat to the other: one can look at both satellite and ground station constellations simultaneously.

For ground stations one is limited to locations of suitable land so the selection will be less than optimum. One can suppose a perfect constellation of satellites but it too will deteriorate if one or more satellites becomes inoperative.

If there is only one ground station, the geometric minimum number of satellites that can provide coverage throughout the world is four.

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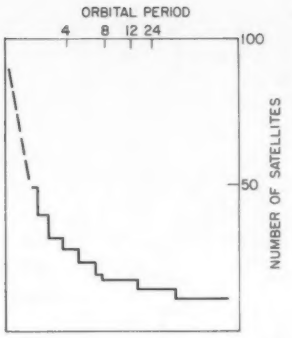

Figure 10

Similarly if there is only one satellite, the minimum number of ground stations is four. To have such coverage by four satellites they must be at or near the apices of a tetrahedron and for a minimum of 10° elevation angle they must be above 25,000 miles. The problem that makes a constellation unusable for satellites is that such a dynamic constellation relationship can be realized only momentarily. The ground station complex is usable provided one can find suitable politically stable locations and the satellites are high enough to be seen for the required portion of the orbit.

The practical minimum number of satellites that will provide at least one satellite visible everywhere from a stable configuration is six, three in each of two planes. For such satellites the minimum altitude required is 6500 miles to provide a minimum elevation angle of 10°. To have three satellites visible it is sufficient to triple this number to 18. The minimum number necessary to have three visible above 10° elevation angle appears to be 12 as shown in Figure 10.

The gist of the above discussion amounts to this:

1. The minimum number of satellites required in order that there be three in view at all times is 12.
2. The minimum number of ground stations required to have all the satellites in view is four.

Since the same geometrical argument is used for both cases the requirement can be satisfied simultaneously. (Though at the lower altitudes the four ground stations will not see the satellites at all times.)

One can look at the constellation again with the idea that perhaps fewer satellites could be used or perhaps a few more would do the job better. A few more satellites does improve the system. The principal reason that more satellites are desirable is that, while three satellites in use are enough for navigation, occasionally one must have a fourth in order to correct one's clock.

With polar satellites the equatorial regions are those that are covered least. Accordingly, coverage at the equator will determine the worst

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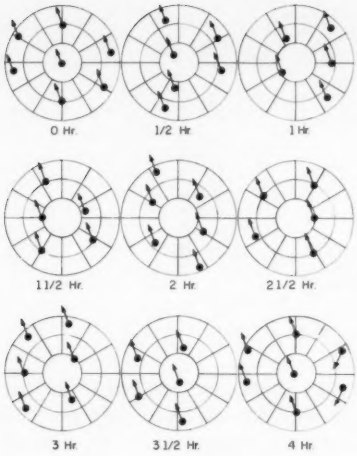

Figure 11 — 3 × 8 constellation of 12 hour satellites

case. Figure 11 shows the coverage for an observer at the equator as the satellites change throughout the first six hours of the day. It is seen that a minimum of four are available over this period. Consequently, we can assume that a three plane, eight satellites per plane, constellation is sufficient and the loss of one or two satellites in such a constellation is not catastrophic.

Only one item remains to be considered. We now have an idea of the number of satellite planes, the number of satellites per plane, the inclination of the planes and the altitude of the satellites. The one item remaining is the effect of eccentricity of the satellite orbit. One difficulty related to eccentricity, assuming a stable satellite clock, is the effect of undesired changes in the clock frequency. The effects are relativistic in origin and are associated with the varying gravitational field of an eccentric orbit. The clock frequency changes and the phase output integrates these changes. Figure 12 shows the magnitude of this effect versus orbit eccentricity. It is seen that, depending on the accuracy desired, the relativity effect can be significant. Obviously a circular orbit should be used.

Another problem concerns the relationship between ground station locations and the clock in the satellite. If one limits ground stations to U.S. possessions he finds a different optimum altitude. In this case each satellite is out of view from a ground station for approximately one half orbit once a day. During this half orbit the error which occurs in the clock cannot be corrected.

The error in satellite position due to gravitational anomalies is a function of altitude decreasing with altitude. The error in the satellite clock is also a function of altitude, increasing with altitude. Figures 13 and

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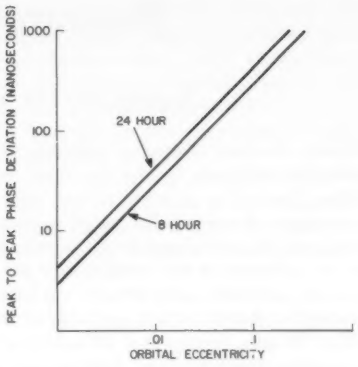

Figure 12 — Error in satellite clocks due to relativistic effects on eccentric orbits

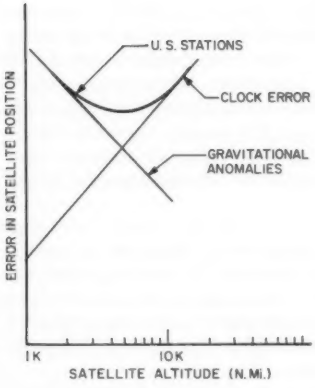

Figure 13

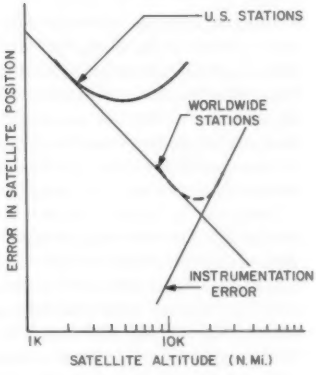

Figure 14

14 show a plot of the two effects and their sum. It is seen that a minimum error occurs at an altitude of approximately 8000 miles.

Therefore the proposal recommends that for a U.S. based satellite navigation system the optimum altitude is about 8000 miles and the constellation should be made up of satellites in circular, polar orbits.

Navy Sponsored Conferences

Second Conference on Numerical Methods in Fluid Dynamics to be held at the University of California, from 16-19 September, 1970.

41st Symposium on Shock and Vibration to be held at the Air Force Academy, Colorado, from 27-29 October, 1970.

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Research Notes

X-Ray Survey of Centaurus A

With its discovery about five years ago, the cosmological background radiation became the strongest evidence for the "big bang" theory of creation and against the continuous creation theory. The observed diffuse microwave radiation from space was attributed to the afterglow of a primordial fireball, whose original temperature exceeded 10^{10} degrees Kelvin and has now cooled to 2.7 degrees Kelvin. To confirm this model, it is essential that the spectrum of the radiation have the characteristic black-body shape, peaking at about one millimeter in the infrared and falling off rapidly toward submillimeter and radio wavelengths. Recent rocket and balloon observations have indicated an infrared flux perhaps 50 times greater than the predicted 2.7 degree black-body value. This high flux is inconsistent with big-bang models and some astrophysicists have suggested that it is produced by a host of discrete sources simulating an almost diffuse field of emission.

Now, an x-ray survey of the radio galaxy, Centaurus A, reported in *Science*, 24 July (1970), by the rocket astronomy group of the Naval Research Laboratory, provides evidence against the existence of infrared background fluxes in excess of the 3-degree radiation which is predicted by the "big bang" cosmology. It may seem strange that information about the infrared background can be obtained from x-ray observations, but the relationship is based on the conversion of infrared photons to x-ray quanta by collisions with cosmic ray electrons which are generated in the radio galaxy. The process, known as inverse Compton scattering, transfers a small part of the billion-volt energy of a typical cosmic ray electron to a millivolt infrared photon, thus raising the photon to an energy of several thousand volts in the x-ray range.

Centaurus A is typical of the class of powerful radio galaxies that consist of two large clouds of relativistic electrons and magnetic fields symmetrically disposed on opposite sides of an optical galaxy, out of which the high energy plasma has been exploded. The rocket-borne x-ray telescope scanned the radio plasma clouds and found a very low level of x-ray emission, consistent with a 3-degree background radiation, but about 50 times weaker than the flux expected from a 7- or 8-degree background, as has been suggested by the recent rocket and balloon infrared measurements.

Previous to the present x-ray measurements, perhaps the strongest argument against the high infrared flux has been based on studies of interstellar absorption by CN, CH and CH^+. The observations give upper limits at wavelengths of 1.32, 0.559 and 0.359 mm, which fall well below the measured rocket and balloon infrared fluxes. However, it has been argued that it is possible for the infrared to be concentrated in sharp spectral lines, which do not coincide with the wavelengths examined by the interstellar molecular absorption technique.

The possibility of the existence of a much stronger than 3-degree background radiation has been used by some astronomers to explain the unexpectedly high fluxes of gamma rays first reported from the OSO-3 satellite observatory. The early analysis of OSO-3 data implied a flux some 10 to 20 times higher than expected from the process of cosmic ray collisions with interstellar gas. It was suggested that Compton collisions with infrared background photons could be responsible if the background radiation temperature were indeed as high as the 7 or 8 degrees indicated by the rocket flights. However, recent recalibration of the satellite-type of instrument has altered the figure for its efficiency so that the estimate of gamma ray flux is more nearly consistent with the 3-degree background.

Further difficulties associated with a high infrared background develop in the interpretation of cosmic ray survival times. The electron component of cosmic rays is steadily lost by Compton scattering and a high infrared background would reduce the lifetime from of the order of a million years for a 3-degree background to less than 10^5 years. This shorter

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life, taken with the associated evidence of the total number of collisions endured by cosmic rays with interstellar gas, leads to an unacceptably high density of interstellar matter.

Continuing measurements of the isotropy of the microwave portion of the 3-degree spectrum offer increasing evidence against the possibility that the background is simply the sum of discrete sources. The observed isotropy shows that fluctuations in temperature are less than 0.004 deg K over angular fields of 12 arc minutes. Such extreme isotropy strongly favors the diffuse model over the discrete source model.

Future x-ray measurements, combined with more accurate infrared observations, offer the possibility of accurately defining the structure of magnetic fields in radio galaxies and the ratio of the electron component to the nucleonic component of the cosmic rays. These observations will also make it possible to define the energy budget of a radio galaxy much more precisely than is now possible.

CNR-CNM Workshop on Naval Applications of Superconductivity

The workshop will be at the Navy Ship Research and Development Laboratory, Panama City, Florida 32401, November 4-5-6, 1970. The workshop classification is secret.

The purpose of this workshop is to bring together representatives of all research and development groups in the Navy concerned with the present and future applications of superconducting materials and devices. Active participants will include scientists, engineers, administrators, and fleet personnel who will exchange information about their current programs and future plans in these fields. Particular emphasis will be placed on specific areas of superconducting technology which have import on future naval requirements.

Some of the topics to be discussed are: (1) superconducting motors and generators, (2) superconducting magnetometers and gradiometers, (3) superconducting infrared sensors, (4) superconducting magnets, and (5) superconducting quantum electronics.

System applications to be considered include (1) propulsion, (2) electric power generation, (3) minesweeping, (4) anti-submarine warfare, (5) surveillance, and (6) degaussing.

Among the intended benefits to the participants of this workshop is the development of an appreciation and an overview of the Navy's total research and development programs and plans in the field of superconducting technology.

It is planned to have available a Navy plane for round-trip transportation from Washington, D.C. to Panama City, Florida, for East Coast attendees leaving on 3 November. Those persons interested in participating in this workshop please contact

Edgar A. Edelsack
Physics Programs (Code 421)
Office of Naval Research, Room 332
800 N. Quincy Street
Arlington, Va. 22217
Telephone – 202 - Ox2-4221

The program and details on hotels, motels, *etc.* will be distributed early in September.

Retroreflection Experiment Benefits ONR

Low-light-level detection techniques developed on the highly publicized (Science, 23 Jan., 30 Jan. 1970; Scientific American, March 1970) laser ranging retroreflector project associated with the Apollo 11 moon landing last July indirectly benefited a project

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on critical light scattering at the University of Maryland supported by the Physics Program of ONR. Both projects are under supervision of Professor C. O. Alley. The laser retro-reflector bank (an assembly of cube corner mirrors, which by their geometry reflect back any light beam exactly parallel to the incoming beam) was left on the surface of the moon. Time measurements between emission and reception of a high power laser beam from earth (reflected by this mirror system) give the earth-moon separation to high precision. Since the return signal is weak, special techniques are required to detect single photoelectrons produced by the low intensity. These same advanced techniques were also used by Alley and his coworkers on the ONR contract to study coherent scattering of light in fluids near their critical points in order to determine the nature of critical density fluctuations. These long-range fluctuations in density are similar thermodynamically to superconducting, magnetic and order-disorder (alloy) transitions.

Navy Studies Improved Technique for Removing Heat

The Navy is studying an improved technique for getting rid of heat in cooling its ships and aircraft.

Research is focused on making use of a recently developed heat-conducting device known as a heat pipe, which is able to transport large amounts of heat with only small losses and does not require external pumping action or any other working parts.

In principle the device is a pipe closed at each end and lined internally with porous material or "wick" impregnated with a fluid. When one end is subjected to heat, the fluid turns into vapor, which is pushed to the cool end by the difference in pressure between the hot and cool end. Upon reaching the cool end, the vapor is condensed, releasing the heat at that point. Surface tension then forces the fluid to travel back via capillary action. When the fluid reaches the hot end, the cycle is repeated.

The working fluid would vary according to the temperatures encountered. The Navy is concentrating on the use of water as meeting the temperature needs aboard ships and aircraft.

Research is being conducted by the University of New Mexico, Albuquerque, N.M., under a contract with the Office of Naval Research on the proper design of water-saturated wicks about which little is known. Most of the work underway is concerned with testing various materials and geometries for the wick. The overall objective is to improve the performance and lessen the heat loss between the two ends of the pipe.

Specific applications of an efficient water-wick heat pipe would be to disperse heat generated by electronic equipment and electric motors, removal of waste heat from power plants and the cooling of leading edges of high-speed aircraft.

Application of New Method of Analyzing Operator Workload to Design of Sonar Systems

The analytic technique is based on recent concepts of the structure of the intellect, developed by Dr. J. P. Guilford under contract with ONR. The method involves collection of data on the amount of each type of intellective activity required in each task performed by the operator, and the "taxation" of difficulty of the mental effort of each activity. The data indicates areas of operation mental overload, and suggests needs for equipment redesign, training, and training devices.

The method has recently been employed by both Sanders Associates and by Honeywell, Inc. in the design of two sonar systems. In both cases the work is aimed at preventing system performance from becoming degraded because of operator overload.

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Navy Winner at International Science Fair

RADM Thomas B. Owen is presenting to Ronald Lee Amey of Allentown, Pennsylvania a Navy Science Cruiser Certificate. The Navy chose Amey's project, "Analytical Study of Balanus Adhesive," for first place at the International Science Fair. In January 1971 Amey will go to Tokyo as a representative of the Navy to exhibit his project at the 14th Annual Japan Student Science Awards Fair.

Converted Navy Gun Ideal Research Tool

Naval Research Laboratory (NRL) scientists have converted an old 16-inch Navy gun liner into a water-filled acoustic impedance tube which can be operated at high pressure. This conversion has saved the Laboratory thousands of dollars and provided an indispensible research tool for investigating the acoustic properties of materials used in deep-diving vessels.

The Naval Research Laboratory employed the Army Materiel Command's Watervliet Arsenal, Watervliet, N.Y., for the unique job of performing the machining and welding required by the conversion. The arsenal set up the 57-feet, 58,000 pound gun barrel in its giant lathe and then machined the exterior and honed the interior to desired proportions. Watervliet also manufactured and attached the massive end plugs which seal the tube and provide the proper acoustic terminations for use as a pressure testing vessel that will simulate all ocean depths.

Use of the new research tool will allow NRL scientists to test materials for high acoustic intensity deep submergence applications such as underwater acoustic transducers, hydrophones, reflectors and absorbers. It will also be used in investigations of acoustic phenomena associated with explosions and shock waves at high pressure.

Research Physicist James G. Larson and Mechanical Engineer Robert Alvarez of NRL were instrumental in the new development.

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Measurement of Stark Effects

Using the increasingly popular technique of Beam Foil Spectroscopy, Professor Stanley Bashkin at the University of Arizona has measured the Stark effect in the spectra of completely ionized helium and hydrogen ions. Other methods of measurements of the Stark effect depend on arc type sources in bounded containers which make absolute measurements difficult and are restricted to those ions which can be formed in sufficient quantities by the arc source. Other disadvantages are lack of knowledge of the ion population, complications due to the presence of various stages of ionizations and of impurity contributions to backgrounds. With the Beam-Foil technique, accelerated ions are further stripped (or neutralized) and excited in their passage through thin carbon foils. The emerging particles then pass between two parallel plates maintained at a potential difference of 35 keV. The light emitted by the beam is viewed for the transverse and longitudinal polarizations by a spectrograph with a photomultiplier tube detector. The current is measured by a charge collecting electrode which intercepts the beam. As well as measuring the Stark broadening of the lines and relative intensities, by viewing the beam at distances further and further from the foil position, the lifetime of each Stark level can be deduced. Another feature is that ions of different charge states are separated spatially for viewing. Impurity contributions are greatly reduced in this method and currents can be easily measured for making absolute measurements. The technique has potential value in several areas. As a testing ground for atomic structure theorists it can be of great value for providing oscillator strengths, lifetimes, *etc.* In a more practical arena, as more ion species become available for acceleration, entirely new data will become available. These would be useful in plasma behavior diagnostic techniques as related to controlled fusion development or solar corona studies (where forbidden transitions, which are enhanced by the Stark effect, could be studied) or, conceivably, in nuclear weapons explosions.

VXE-6 BI-Polar Crew

Antarctic Support Squadron Six (VXE-6) qualified a nine member Bi-Polar Aircrew in May 1970. The Office of Naval Research (ONR) requested aircraft support services through the Chief of Naval Operations (CNO) to facilitate low level aircraft delivery of underwater sound signals through open water leads in the Arctic ice pack as part of the project, Arctic Ocean Acoustic Investigation. The investigation was aimed at determining the acoustic effects of underwater topography, water depth, and distance over selected paths in a large portion of the Arctic Ocean. VXE-6 received the assignment since its Super Constellation, Phoenix Six, (C-121) (Bu No 131624) has the required low altitude range plus a configuration permitting launching sound signals from the passenger cabin.

The crew of Phoenix Six, accompanied by the Arctic Projects Officer of ONR, three Naval Oceanographic Office ice observers and an ordnanceman from the Naval Air Station, Quonset Point flew four flights from Thule Air Base, Greenland and Eielson Air Force Base, Alaska over the polar ice pack from 6 May through 11 May 1970. On 8 May 1970 Phoenix Six passed over the North Pole at 2000 hours Greenwich time and consigned a properly prepared bottle containing a crew list signed by all aboard to the ice in the hope that it may survive, be carried out of the Arctic Ocean with the ever drifting ice and be recovered on some beach as the ice melts away.

The crew members who constitute the Bi-Polar Aircrew had previously been to the South Pole during routine annual Navy support missions of the Antarctic research sponsored by the National Science Foundation. A crew patch featuring a globe with a penguin and a polar bear each suitably located has been designed.

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NRL Contracts for 17 Billion Watt Laser

The Naval Research Laboratory has contracted nearly a quarter million dollars for the expansion of one of its present laser systems in the advancement of its hot plasmas research program.

Hadron, Inc. of Westbury, New York has received the contract from NRL that calls for the conversion of the present NRL Hadron/CGE 320 laser installation to a 640 system. NRL scientists will thus have at their disposal the highest-power, highest-brightness laser that is commercially available. The 640 system is capable of providing an output energy of 500 joules in a 30 nanosecond pulse and a peak power of some 17 billion watts.

The powerful laser system will be used to deal with the generation of hot plasmas, an experiment which has been extremely difficult to perform before the advent of systems such as the 640.

The new laser system features modular construction which will allow NRL scientists to retain the present 320 system to which amplifiers will be added to upgrade it to the 640 installation. It will be about 35 feet long and will produce a well-collimated output beam some two and one half inches in diameter. The beam will be focused approximately 100 feet from the laser exit.

The Plasma Physics Division headed by Dr. Ramy A. Shanny, Acting Superintendent, conducts both basic and applied research. Examples of effort underway by this division included fusion physics and generation and containment of high-temperature plasmas. This is directed toward eventual power sources for laboratory experiments in astrophysics, electron beams, and high-power lasers.

Deformation in Composite Materials

Professor A. Lawley of Drexel Institute of Technology has recently observed many interesting features of deformation behavior in a wire reinforced composite (stainless steel wires in aluminum) and in a directionally-solidified lamellar eutectic composite ($CuAl_2$ in aluminum).

Under tensile loading to failure, the elastic moduli and yield stresses of both composites were found to agree with predictions based on the rule of mixtures, which requires only that the theory of elasticity be applicable and that the reinforcing phase and binder undergo equal strains. Addition of the reinforcing phase strengthened the aluminum significantly; for example, the yield stress (at a strain = .0001 in./in.) went from only 1,000 to 10,000 psi on introduction of 35 volume percent of stainless steel wire into the aluminum. Examination of the fracture surfaces by scanning electron microscopy showed that the wires separated in individual cup-cone fractures with substantial plastic deformation occurring in both the wire and binder phases and that the initial processing had achieved well-bonded interfaces between the binder and wires.

Under compression testing the Al-$CuAl_2$ lamellar composite again followed predictions of the rule of mixtures; in contrast, the yield stress of the wire reinforced composite exceeded the predicted values by about a factor of eight. Plastic flow in compression occurred by excessive buckling of the reinforcing phases in both composites. But, whereas the eutectic composite the load was borne by both phases and stress transfer across the lamellar-matrix interface was quite effective, in the wire reinforced composite evidently little load transfer occurred across the interface and the wires supported most of the load. This research is aimed at increasing our understanding of the complex distribution of stresses and strains that develops in the reinforcing phase, the binder, and at the interfaces between them, as composites are put under load. Results of the research should aid in the design and development of new and improved composite materials.

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Species Separation in Supersonic Flow

In a study of Relaxation Processes in Gases (under Project SQUID, Yale University), using molecular beam techniques, it was discovered several years ago by J. B. Fenn that in the case of gas mixtures subjected to severe accelerations or decelerations and hence large pressure gradients, there was an enrichment of heavier species exceeding that which can be accounted for by pressure diffusion in the jet. In addition, it was demonstrated that species separation observed in probe sampling experiments could be caused by interaction of the flow with the probe. These results indicated the importance of what happens during the stagnation flow in and after the shock wave induced by the extraction probe. At present there is no theory to account quantitatively for probe-induced separation. Further results of probe-induced species separation have been obtained by Dr. Fenn under conditions which would serve to elucidate the responsible mechanism and which hopefully would be tractable to theoretical analysis. The stagnation point composition was measured with argon-helium mixtures over a range of experimental conditions and a correlation was developed to describe the amount of probe induced separation which was observed. Apart from the scientific interest per se in the dynamic behavior of mixed gases, the magnitude of the measured probe induced separation should stimulate some practical concern. The results show that in sampling with a probe to determine composition in supersonic mixture flow, the criterion of making the probe small so as not to disturb the aerodynamics of the flow is not sufficient. It is necessary to consider possible distortion of composition by species separation in the stagnation process if the probe is too small. It seems likely that probe induced separation accounts for a large part of high thermal recovery factors which have been observed during stagnation of gas mixtures. Perhaps the most interesting prospective application of probe induced separation is in the possible separation of uranium isotopes for nuclear power generation. It is planned to present this information at the next Rarefied Gas Dynamics Symposium which will be in Pisa, Italy, in July.

Accounting for Errors in Inventory

Drs. Morey and Inglehart, Decisions Studies Group have just completed preliminary research on a mathematical procedure for reducing the occurrence of warehouse denials in an inventory system. The procedure recognizes that there are errors in the inventory stock records.

Errors are introduced in an inventory stock record during the stocking point's normal operation in various ways: through time lags, incorrect posting, keypunching errors, and pilferage—to name a few.

Errors have two effects on the system. When physical stocks are less than recorded stocks—warehouse denials result in compromising the stock manager's budget and reducing his ability to provide adequate material support. In the other case, when physical stocks are greater than the recorded stocks, the material order to the warehouse is not released, and plans are made to purchase additional stocks; again the manager's position is compromised.

This paper describes a procedure which will minimize total cost per unit time, yet keep the likelihood of a warehouse denial from occurring between physical inventories at some prescribed level.

These preliminary research results have been transmitted to NAVSUP Research & Development Division through a presentation and the technical report. Future research and development under joint funding is anticipated during FY 71.

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Colorado Tick Fever Virus

By the use of fluorochrome staining, enzymatic digestion tests and biophysical procedures, CAPT I. J. Green, of the Naval Biological Laboratory and the Naval Medical Research Unit No. 1, has been able to show that the genetic material (genome) of Colorado tick fever virus is of a double-stranded RNA nature. This virus is classified among the Ungrouped Arboviruses, *i.e.*, arthropod borne viruses which are not related to Group A or to Group B arboviruses. A recent study of blue-tongue virus of sheep, also an ungrouped arbovirus, by another investigator, has indicated that it, too, contained a double-stranded RNA viral genome. All arboviruses previously studied have been shown to contain not double-but single-stranded viral RNA genomes. The finding that double-stranded RNA genomes are present in some of the ungrouped arboviruses, will necessitate the reclassification of arboviruses into two groups: (1) those containing single-stranded RNA genomes and (2) those containing double-stranded RNA genomes.

Hardiman Gets First Arm

One arm of Hardiman, an advanced man-machine system that will be worn by an operator like an outside skeleton, has been completed and successfully tested.

The steel and aluminum structure, designed to multiply human muscle power and increase man's strength and endurance, is being developed for use by the Army and the Navy. In effect, it will wed the intelligence of man to the muscle power of a forklift.

The General Electric Company, Schenectady, N.Y., is building the Hardiman prototype under contract to the Office of Naval Research, with support also provided by the Army Materiel Command and the Naval Air Systems Command.

Through an advanced system of control linkage and hydraulically-powered servomechanisms, Hardiman will mimic the movements of its operator and permit him to lift and manipulate loads up to 1500 pounds. In the test the single arm enabled a man to lift its design load of 750 pounds.

Hardiman (the name is derived from Human Augmentation Research and Development Investigation) is designed to handle heavy loads in restricted and remote areas where standard equipment is sometimes too cumbersome for the job. Tasks envisioned for Hardiman include loading and handling missiles and other ordnance, loading of heavy items on aircraft, and serving as general cargo handler within confined spaces in ships.

As a labor-saving device on aircraft carrier decks, one Hardiman could free several men from their strenuous work.

Advanced versions of Hardiman might also perform missions in hostile environments, such as underwater construction, salvage, and search-and-rescue operations in the ocean. Modifications, which would allow the operator to manipulate the exoskeleton from a distance, would make it useful in hazardous situations, such as demolition jobs.

The Hardiman arm system is a master-slave system containing eight powered joints: wrist flex, forearm rotate, elbow flex, upper arm rotate, shoulder flex, back flex, thumb tip, and thumb flex joints.

The operator controls the master structure through attachment at three points: the hand, wrist, and the upper forearm. When the operator places the master in a particular configuration, the desynchronization error between the master and the slave is measured at each joint.

These errors are converted to electrical signals and transmitted to electro-hydraulic servo valves which produce differential pressure proportional to the electric signal. This pressure is applied to the slave actuator for the corresponding joint and causes the joint to move in the same direction as the master.

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The slave continues to move until the desynchronization error is reduced to a level that will maintain the system in equilibrium. The pressure is also applied to the force feedback actuator at each joint of the master structure, thereby reflecting load forces to the operator.

The testing of the left arm and hand-assembly of the Hardiman system, which will eventually include two arms as well as two legs, was conducted by attaching the disembodied arm to a fixed stand. By mating his left arm to the mechanical counterpart, a test engineer was easily able to lift loads up to 750 pounds.

Main objective of the test of the arm was stable operation of the arm system under full load. This demanded that the system be operated successfully in six major areas: individual stability of the joints, stability of the joints-in-series, kinematic interactions, mechanical interference, ability of the operator to control the system, and ease of operation.

The high-performance servos developed for the machine, which proved to be completely stable, are considered to be a significant advance in servo technology. The test also demonstrated that it is possible to operate the machine successfully with minimum experience.

Sea Cliff and Turtle

The twin research submarines designed and built at the Electric Boat division of General Dynamics, have completed 13-week sea trials off the Bahamas. The 25-foot, manipulator-equipped subs have returned by support ship to their builder's yard where they are now being readied for delivery to the Naval Ship Systems Command.

Sea Cliff will be operated by the Office of Naval Research at Woods Hole Oceanographic Institution, Woods Hole, Mass. *Turtle* will be operated by the Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) in the Bahamas.

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On the Naval Research Reserve

Officially Activated Research Reserve Companies

There are 78 Research Reserve companies located throughout the United States. These companies are listed below by Naval Districts. The time and place of meeting, address, and name of the commanding officer are included.

NRRC 1-1
1930, 1st & 3rd Mondays, Room 4-270, M.I.T., 77 Massachusetts Avenue, Cambridge, Massachusetts 02138. (LCDR John L. SAMPSON, USNR, 8 Bedford Street, Lexington, Massachusetts 02173.)

NRRC 1-2
1930, 1st & 3rd Wednesdays, Room 114, Naval & Marine Corps Reserve Training Center, Fields Point, Providence, Rhode Island 02905. (LCDR Herbert B. BARLOW, Jr., USNR, 277 Nayatt Road, Barrington, Rhode Island 02806.)

NRRC 1-3
1930, 1st & 3rd Tuesdays. (No meetings during July & August.) Holdsworth Hall, Room 339, University of Massachusetts Campus, Amherst, Massachusetts 02103. (CDR Charles F. COLE, USNR, 21 Columbia Circle, Amherst, Massachusetts 01002.)

NRRC 1-5
1930, 1st, 2nd & 3rd Mondays. (No meetings during July & August.) Alden Research Laboratories Auditorium, Worcester Polytechnic Institute, Holden, Massachusetts 01520. (CDR George (NMN) CAMOUGIS, USNR, 10 Wheeler Avenue, Worcester, Massachusetts 01609.)

NRRC 1-7
1930, 1st & 3rd Tuesdays. (No meetings during July, Aug. & Sept.) College Hall, Room 312, Dartmouth College, Hanover, New Hampshire 03755. CDR Henry E. EBERHARDT, III, USNR, Plainfield, New Hampshire 03781.)

NRRC 3-1
1830, 1st & 3rd Thursdays, 821 United Nations Plaza, 46th & 1st Avenue, New York, New York 10017. (LCDR Peter B. LEDERMAN, USNR, 17 Pittsford Way, New Providence, New Jersey 07974.)

NRRC 3-2
1930, 2nd & 4th Mondays, U.S. Merchant Marine Academy, Kings Point, New York 11024. (LCDR John G. BUSHARIS, USNR, 134 Madisonville Road, Basking Ridge, New Jersey 10502.)

NRRC 3-3
2000, 2nd & 4th Mondays, Veterans Hospital (Room 502), 3495 Bailey Avenue, Buffalo, New York 14215. (LCDR Sheldon M. MARKEL, USNR, 205 Irving Terrace, Buffalo, New York 14223.)

NRRC 3-4
2000, 2nd & 4th Mondays, Bausch & Lomb Hall, Room 109, University of Rochester, Rochester, New York 14627. (LT Byron "W." BUELL, USNR, 72 Thatcher Road, Rochester, New York 14617.)

NRRC 3-5
2000, 1st & 3rd Thursdays, Hartford Electric Light Company, 176 Cumberland Avenue, Wethersfield, Connecticutt 06169. (LCDR John M. McISAAC, USNR, 6 Gretel Lane, Simsbury, Connecticut 06070.)

NRRC 3-7
2000, 2nd & 4th Thursdays, Naval Reserve Training Center, Scotia, New York 12302. (CDR Benjamin B. LOCKETT, USNR, 1804 Nott Street, Schenectady, New York 12309.)

NRRC 3-8
1900, 2nd & 4th Tuesdays, Young & Rubican, Inc., 6th Floor, 285 Madison Avenue, New York, New York 10017. (LCDR

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Harold M. BREWSTER, USNR, 852 Union Avenue, Hillside, New Jersey 07205.)

NRRC 3-9
1930, 2nd & 3rd Wednesdays, Brookhaven National Laboratory, Upton, Long Island, New York 11973. (CAPT James S. ROBERTSON, USNR, 28 Gnarled Hollow Road, East Setauket, New York 11733.)

NRRC 3-14
1800, 1st & 3rd Tuesdays, Naval Reserve Training Center, 75 Oakley Street, Poughkeepsie, New York 12602. (LCDR Walter L. GILMAN, USNR, Box 811, Port Ewen, New York 12466.)

NRRC 3-16
2000, 1st & 3rd Thursdays, Sheffield Lab. of Engineering Mechanics, 51 Prospect Street, New Haven, Connecticut 06511. (CDR Saul L. BAHN, USNR, 266 Dyer Street, New Haven, Connecticut 06511.)

NRRC 3-18
1945, 1st & 3rd Mondays, Illick Hall, College of Forestry, Syracuse University, Syracuse, New York 13210. (LCDR Arnold A. BITTERMAN, USNR, 7237 Coventry Road, East Syracuse, New York 13057.)

NRRC 4-1
2000, 1st & 3rd Wednesdays, FMC Corp. Research Center, US #1, Princeton, New Jersey 08540. (CDR Hugo (NMN) STANGE, USNR, 19 Hamilton Avenue, Princeton, New Jersey 08540.)

NRRC 4-3
2000, 1st & 3rd Thursdays, Naval & Marine Corps Reserve Training Center, 4902 Forbes Avenue, Pittsburgh, Pennsylvania 15213. (CDR Franklyn L. CUTRONE, USNR, 1012 Covington Place, Allison Park, Pennsylvania 15101.)

NRRC 4-4
1930, Mondays, 316 Wagner Building, Pennsylvania State University, University Park, Pennsylvania 16801. (LCDR Robert C. BALDWIN, USNR,132 South Sparks Street, State College, Pennsylvania 16801.)

NRRC 4-5
2000, Alternate Mondays, Naval & Marine Corps Reserve Training Center, 3920 Kirkwood Highway, Wilmington, Delaware 19808. (CDR John M. MOORE, Jr., USNR, 2030 Harwyn Road, Wilmington, Delaware 19810.)

NRRC 4-7
1930, Alternate Thursdays. (No meetings during July & Aug.) Battelle Memorial Institute, South Conference Room, 505 King Avenue, Columbus, Ohio 43201. (LCDR Charles R. McLEAN, USNR, 69 W. College Avenue, Westerville, Ohio 43081.)

NRRC 4-8
1800, 1st & 3rd Mondays, Naval & Marine Corps Reserve Training Center, 1089 East Ninth Street, Cleveland, Ohio 44114. (LT Peter J. ROMANOLI, USNR, 11833 Clarkwood Drive, Chardon, Ohio 44024.)

NRRC 4-11
1900, Alternate Tuesdays, Naval & Marine Corps Reserve Training Center, Room 37, Gilbert Avenue & Victory Parkwar, Cincinnati, Ohio 45207. (CDR John E. WHITE, USNR, 9757 Overview Lane, Cincinnati, Ohio 45231.)

NRRC 4-12
1930, Alternate Tuesdays. (No meetings during July & Aug.) Naval Air Development Center, Johnsville, Warminster, Pennsylvania 18974. (CDR William H. HAZLETT, Jr., USNR, Bit-a-Bux, River Road, Upper Black Eddy, Pennsylvania 18972.)

NRRC 4-13
2000, 1st & 3rd Mondays, Franklin Institute Laboratory, 20th & Race Streets, Philadelphia, Pennsylvania 19112. (CDR Alfred A. LITTLE, USNR, 461 Paxon Hollow Road, Media, Pennsylvania 19063.)

NRRC 5-2
2000, Mondays. (No meetings during July & Aug.) Room 310, Hutcheson Hall, Virginia Polytechnic Institute, Blacksburg,

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Virginia 24061. (LT William P. HARRISON, Jr., USNR, P. O. Box 364, Blacksburg, Virginia 24060.)

NRRC 5-4
1945, 1st & 3rd Thursdays, Marine Corps Armory, Hamlet & Chesley Avenues, Baltimore, Maryland. (LCDR Herman D. RAYNES, USNR, 1015 Smoke Tree Road, Baltimore, Maryland 21208.)

NRRC 5-8
2000. 2nd & 4th Thursdays, National Academy of Sciences, 2102 Constitution Avenue, N.W., Washington, D.C. (CDR Theron W. DAVIDSON, USNR, P. O. Box 7, Lexington Park, Maryland 20653.)

NRRC 5-9
1630, 1st & 3rd Fridays. (Except during First Quarter; meetings are alternate Wednesdays.) Naval Research Laboratory, 4555 Overlook Avenue, Washington, D.C. 20390. (CDR Russell H. KYSER, USNR, 5985 Ridge Crest Drive, Suitland, Maryland 20023.

NRRC 5-10
2000, 2nd & 4th Tuesdays, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland 20014. (LCDR Hugh R. HOPPER, USNR, 13539 Georgia Avenue, Apt. 204, Silver Spring, Maryland 20906.)

NRRC 5-11
2000, 2nd & 4th Tuesdays, Annapolis Division, Ships Research & Development Center, Annapolis, Maryland 21402. (CDR Frederick ELIOT, USNR, 1513 Eton Way, Crofton, Maryland 21113.)

NRRC 5-12
1900, 2nd & 4th Mondays, Building 1200, Room A135, Naval Weapons Laboratory, Dahlgren, Virginia 22448. (LCDR David S. MAYEVAC, USNR, Box 149, Dahlgren, Virginia 22448.)

NRRC 6-1
1930, 1st, 2nd & 3rd Thursdays. (No meetings during first quarter.) Naval & Marine Corps Reserve Training Center, 274 Fifth Street, N.W., Atlanta, Georgia 30318. (CDR James NEIHEISEL, USNR, 444 Pine Ridge Trail, Marietta, Georgia 30060.)

NRRC 6-3
1930, 2nd & 4th Wednesdays, Army Reserve Armory, Elza Gate, Oak Ridge, Tennessee 37830. (LCDR Woodrow W. PITT, Jr., USNR, 254 Iroquois Road, Oak Ridge, Tennessee 37830.)

NRRC 6-6
1830, Mondays. (No meetings during first quarter.) NROTC Building, University of North Carolina, Chapel Hill, North Carolina. (LCDR David G. WARREN, USNR, 423 Ridgefield Road, Chapel Hill, North Carolina 27514.)

NRRC 6-8
1930, 1st, 3rd & 5th Mondays, Naval Reserve Training Center, Livingston & Parramore Streets, Orlando, Florida. (LCDR Glenn W. HOHMAN, USNR, 1910 Summerland Avenue, Winter Park, Florida 32789.)

NRRC 6-9
1900, 1st, 3rd & 4th Mondays, Smith Hall, Navy Supply Corps School, Athens, Georgia. (LCDR Louis DE VORSEY, Jr., USNR, 355 Kings Road, Athens, Georgia 30601.)

NRRC 6-17
1900, Mondays, Naval Reserve Training Center, 203 Leeman Ferry Road, S.W., Huntsville, Alabama. (LCDR George P. RITCHIE, Jr., USNR, 1004 Conrad Drive, S.E., Huntsville, Alabama 35803.)

NRRC 6-18
2000, 1st & 3rd Mondays, School of Engineering, Vanderbilt University, Nashville, Tennessee. (LCDR Hugh G. ELDREDGE, Jr., USNR, Imperial House Apts., Apt. 810, Bosley Springs Road, Nashville, Tennessee 37205.)

NRRC 6-19
1930, 1st, 2nd & 3rd Thursdays, Naval Reserve Training Center, 12 Meadow Street, Chattanooga, Tennessee 37405. (LCDR Walter J. ROGERS, Jr., USNR, 203 West Daytona Drive, Chattanooga, Tennessee 37415.)

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NRRC 8-1
1930, Alternate Tuesdays, Richardson Memorial Building, Room 203, Tulane University, 6823 St. Charles Avenue, New Orleans, Louisiana 70118. (CAPT Robert D. COSGROVE, USNR, 2846 State Street, New Orleans, Louisiana 70118.)

NRRC 8-3
1930, Mondays, Petroleum Engineering Building, Texas A&M College, College tion, Texas 77843. (CDR Ronald DARBY, USNR, 3503 Carter Creek Parkway, Bryan, Texas 77801.)

NRRC 8-4
1930, 1st & 3rd Wednesdays, Naval Reserve Training Center, Houston, Texas 77025. (LCDR Charles N. COLEMAN, USNR, 7914 Skyline Drive, Houston, Texas 77042.)

NRRC 8-5
1900, Mondays, Experimental Science Building 115, University of Texas, Austin, Texas 78712. (CDR Thomas E. BURRIS, USNR, 8071 N. Lamar Boulevard, Austin, Texas 78753.)

NRRC 8-7
1930, Mondays, NROTC Building, University of New Mexico, Albuquerque, New Mexico 87106. (CDR Calvin B. ROGERS, USNR, 1312 Alcazar N.E., Albuquerque, New Mexico 87110.)

NRRC 8-8
1930, 1st & 3rd Tuesdays, Post Office Building, Bartlesville, Oklahoma 74003. (LCDR Paul D. FARLEY, USNR, 5012 E. F. Phillips Blvd., Bartlesville, Oklahoma 74003.)

NRRC 8-9
1700, 1st & 3rd Tuesdays, Lecture Room Administration Building, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87544. (LCDR Lawry W. MANN, USNR, 3208-A Villa, Los Alamos, New Mexico 87544.)

NRRC 8-12
2000, 1st & 3rd Tuesdays, Santa Fe Building, 114 Commerce Street, Dallas, Texas 75202. (LCDR Paul D. MAYCOCK, USNR, 204 Shadywood Lane, Richardson, Texas 75080.)

NRRC 8-13
1930, Thursdays, Room 147, Physical Sciences Building, Oklahoma State University, Stillwater, Oklahoma 74075. (CDR Theodore L. AGNEW, USNR, 1216 N. Lincoln Street, Stillwater, Oklahoma 74074.)

NRRC 9-1
1900, 2nd & 4th Tuesdays, Naval Armory, Randolph at the Lake, Chicago, Illinois 60601. (CDR John C. SIEBERT, USNR, 1646 N. Sedgwick, Chicago, Illinois 60614.)

NRRC 9-3
1930, Mondays. (Varied dates July, Aug. & Sept.) 62 North Hall, University of Michigan, Ann Arbor, Michigan 48104. (LCDR William G. PRICE, USNR, 2312 Walter Drive, Ann Arbor, Michigan 48103.)

NRRC 9-4
2000, 2nd & 4th Tuesdays, Naval & Marine Corps Reserve Training Center, Milwaukee, Wisconsin 53207. (CAPT John E. HOUSIAUX, USNR, 7490 North Navajo Road, Milwaukee, Wisconsin 53217.)

NRRC 9-5
1900, 1st, 2nd & 3rd Wednesdays, NROTC Building, Iowa State College, Ames, Iowa 50010. (LCDR Martin D. SECKER, USNR, Timberland Heights, RR 4, Ames, Iowa 50010.)

NRRC 9-6
1930, 2nd & 4th Mondays, Room 208, Mechanical Eng. Building, University of Minneapolis, Minnesota 55414. (CDR Carl E. LEWIS, USNR, 7908 28th Avenue, North, Minneapolis, Minnesota 55427.)

NRRC 9-7
1900, Tuesdays, C/O NROTC Unit, AES Annex, Purdue University, Lafayette, Indiana 47907. (LT Curtis M. PAULSEN, USNR, Box 992, St. Joseph's College, Rensselaer, Indiana 47928.)

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NRRC 9-8
1900, 2nd & 4th Wednesdays, Meramec Community College, St. Louis, Missouri 63130. (LCDR William A. WUNDRACK, USNR, 24 Black Oak Drive, St. Louis, Missouri 63127.)

NRRC 9-10
1800, Alternate Tuesdays, Sargent Hall, Northwestern University, Evanston, Illinois 60201. (LCDR Edward L. DEAM, USNR, 1585 Ridge Road, Highland Park, Illinois 60035.)

NRRC 9-12
1930, Thursdays, Wood Utilization Laboratory, Colorado State University, Fort Collins, Colorado 80521. (LCDR Charles P. REID, USNR, 1912 Paunee, Fort Collins, Colorado 80521.)

NRRC 9-16
1930, Mondays, 221 Computing Center, Michigan State University, East Lansing, Michigan. (LCDR Charles E. CRESS, USNR, 1918 Tomahawk, Okemos, Michigan 48864.)

NRRC 9-19
1930, Mondays, Naval Reserve Training Facility, Iowa City, Iowa 52240. (LCDR William F. MCCORMICK, USNR, 5 Washington Place, Iowa City, Iowa 52240.)

NRRC 9-21
1930, 1st & 2nd Tuesdays, Denver Federal Center, Denver, Colorado 80225. (LCDR Jack A. HORST, USNR, 5260 West Rowland Avenue, Littleton, Colorado 80120.)

NRRC 9-23
1930, 2nd & 4th Wednesdays, Argonne National Laboratory, Argonne, Illinois 60439. (LCDR John E. BAUBLITZ, USNR, 1449 Arrow Wood Lane, Downers Grove, Illinois 60515.)

NRRC 9-26
1930, Tuesdays, Naval Reserve Training Center, Colorado Springs, Colorado 80906. (CDR James H. RYAN, USNR, 2205 Drakestone Drive, Colorado Springs, Colorado 80909.)

NRRC 9-27
2000, Thursdays, Naval Reserve Training Center, Building 512, Great Lakes, Illinois 60088. (CDR Carl E. SALL, USNR, 800 Maple Court, Elk Grove Village, Illinois 60007.)

NRRC 9-28
1900, Wednesdays, NROTC Armory, 6th Street & Stewart Road, Columbia, Missouri 65201. (LCDR William D. NOTEBOOM, USNR, 605 Maplewood Drive, Columbia, Missouri 65201.)

NRRC 11-2
2000, 2nd & 4th Mondays, Naval & Marine Corps Reserve Training Center, 2727 Paloma Street, Pasadena, California 91107. (LCDR Jack H. BURTHE, USNR, 408 S. Fircroft Street, West Covina, California 91790.)

NRRC 11-5
1930, 2nd, 3rd & 4th Tuesdays, Naval Reserve Training Center, San Diego, California 92133. (CDR Wade E. SELPH, USNR, Route 1, Box N-20, Del Mar, California 92014.)

NRRC 11-7
2000, 1st & 3rd Thursdays, Naval & Marine Corps Reserve Training Center, 1000 S. Alvernon Way, Tucson, Arizona 85711. (CAPT James KAY, USNR, 924 South Magnolia, Tucson, Arizona 85711.)

NRRC 11-11
2000, 1st & 3rd Mondays, Naval & Marine Corps Reserve Training Center, 3400 Airport Avenue, Santa Monica, California 90405. (LCDR Paul P. LEO, USNR, 29216 South Firthridge, Palos Verdes Peninsula, California 90274.)

NRRC 12-2
1700, 1st, 2nd & 3rd Mondays, Room 118, Building 311, Lawrence Radiation Laboratory, Livermore, California. (CDR Gale K. HOVEY, USNR, 1312 Roselli Drive, Livermore, California 94550.)

NRRC 12-3
1930, 1st & 3rd Wednesdays, Lockheed

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Missile & Space Company, Building 181, Sunnyvale, California 94000. (LCDR Kermit N. ARNOLD, USNR, 2841 Pruneridge Avenue, Santa Clara, California 95051.)

NRRC 12-4
2000, Thursdays, Naval Reserve Training Center, 4590 E. Ventura Avenue, Fresno, California. (LCDR Wayne E. BIEHLER, USNR, 3314 Griffith Way. Fresno, California 93726.)

NRRC 12-5
1930, 2nd & 4th Wednesdays, Room 246, Cory Hall, University of California, Berkeley, California. (CDR Walter D. THOMAS, Jr., USNR, 2173 Roskelley Drive, Concord, California 94520.)

NRRC 12-6
1930, 1st, 2nd & 4th Thursdays, Lecture Room, Unit III, University of California Davis Medical School, Davis, California. (CDR Robert H. BROWNSON, USNR, 2927 Country Club Circle, El Macero, California 95618.)

NRRC 12-8
2000, 2nd, 3rd & 4th Wednesdays, Room S-136, Naval Postgraduate School, Monterey, California. (CDR Oscar B. WILSON, Jr., USNR, 14 Cuesta Vista Drive, Monterey, California 93940.)

NRRC 13-1
1930, 1st, 2nd & 3rd Mondays, Naval Reserve Training Center, 860 Terry Avenue, North, Seattle, Washington 98109. (CDR Ambrose A. CLEGG, Jr., USNR, 8304 S. E. 62nd, Mercer Island, Washington 98040.)

NRRC 13-4
2000, 2nd & 4th Tuesdays, Naval & Marine Corps Reserve Training Center, Swan Island, Portland, Oregon 97217. (CDR Delmer L. KUNS, USNR, 14465 S.W. 114th Avenue, Tigard, Oregon 97223.)

NRRC 13-5
1930, 2nd & 4th Mondays, NROTC Armory, Oregon State University, Corvallis, Oregon 97330. (CDR James D. HALL, USNR, 3106 Harrison Street, Corvallis, Oregon 97330.)

NRL Builds Device for Low Temperature Research

The Naval Research Laboratory has completed the construction of a new refrigerator in their low temperature laboratory. This refrigerator, known as a helium 3-helium 4 dilution refrigerator because it uses these two isotopes of helium in the cooling process, is capable of producing temperatures near absolute zero (−460°F) for indefinite periods of time.

While the principle of the dilution refrigerator was first proposed in the early 1950's, it was not until 1966 that the first successful model was built. Since that time many low temperature laboratories have started to use them for various low temperature studies. The Navy, which recognized the scientific impact of this new type of refrigeration, has added a dilution refrigerator facility to its low temperature laboratory and recently sponsored an international conference on the design and use of these refrigerators. This conference, held in April 1970, was attended by over 150 scientists actively working in the field of dilution refrigeration.

Dr. Donald U. Gubser, who designed and built the helium 3-helium 4 dilution refrigerator at NRL, describes the principal advantages of the refrigerator over other forms of cooling as twofold:

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(1) dilution refrigeration is the only means of producing continuous cooling at these low temperatures, and
(2) large magnet facilities necessary in other types of cooling are not necessary in dilution cooling.

Since the process is continuous, scientists will be able to cool large samples of material and will be able to keep them cold to study their properties for days or even weeks. Also, since large magnets are not needed, the availability of low temperatures for use in laboratories is greatly enhanced.

Scientists at the Naval Research Laboratory will use this new facility to study the properties of matter near absolute zero in temperature. One particular property at these temperatures which interests the Navy very much is the phenomenon of superconductivity. Once a material becomes superconducting (only at temperatures near absolute zero), it loses all of its electrical resistance to current flow. Another property which is just as important to scientists is that a superconductor is a perfect shield for magnetic fields. Utilizing these two basic properties, the Navy has been able to design and build very intricate electronic detection gear which is far more sensitive than anything previously built. While sensitive electronic gear has already put superconductivity and low temperatures to work, many other areas are being studied for potential applications. Transmission lines, power generators, and even high speed trains have all been proposed as possible places to use superconducting materials.

Although the potential uses of superconductivity are great, there is much to be learned of the phenomena before it can be realistically applied. For this reason, the Navy has for years been supporting research on superconductor at very low temperatures. The low temperature laboratory at NRL has been one of the leading laboratories in superconductivity research and with the completion of the new helium 3-helium 4 dilution refrigerator, the Navy will continue its quest for more information about matter near absolute zero in temperature.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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A passive ranging technique was conceived at ONR in 1964. Since then it has inspired other navigation proposals and has become a prime candidate for a Defense Navigation Satellite System.

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Petroleum Prone *– In a special research project for the Office of Naval Research, the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, Calif., is attempting to isolate bacteria with the most ravenous appetite for oil. This photograph, taken by NCEL biologists, is magnified approximately 625 times. It shows a single drop of oil apparently being devoured by literally millions of bacteria, members of Genus Pseudomonas. The bacteria were taken from one of dozens of samples of beach sand in Ventura and Santa Barbara Counties. Each football-shaped oval seen is a colony of more than a million bacteria. The Laboratory hopes that upon isolation a method can be developed to increase the rate of consumption by oil-digesting bacteria.*

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